Estimation of the peak accelerating voltage from the synchrotron frequency at the TEVATRON

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April 13, 2005

The frequency of the synchrotron oscillations f_s can be defined as :

$$f_s = f_0 \times \sqrt{\frac{eVh\alpha}{2\pi Es}} \quad (1)$$

where f_0 is the beam revolution frequency, V the peak accelerating voltage, h is the harmonic number, α the momentum compaction and E_s the beam energy. Figure 1 shows the evolution of the synchrotron frequency f_s as a function of the peak accelerating voltage for a 150 GeV proton beam and

- $f_0 = 47.7$ kHz
- $h = 1113$
- $\alpha = 2.82 \cdot 10^{-3}$ (from measurement at 150 GeV, [1])
- $E_s = 150$ GeV

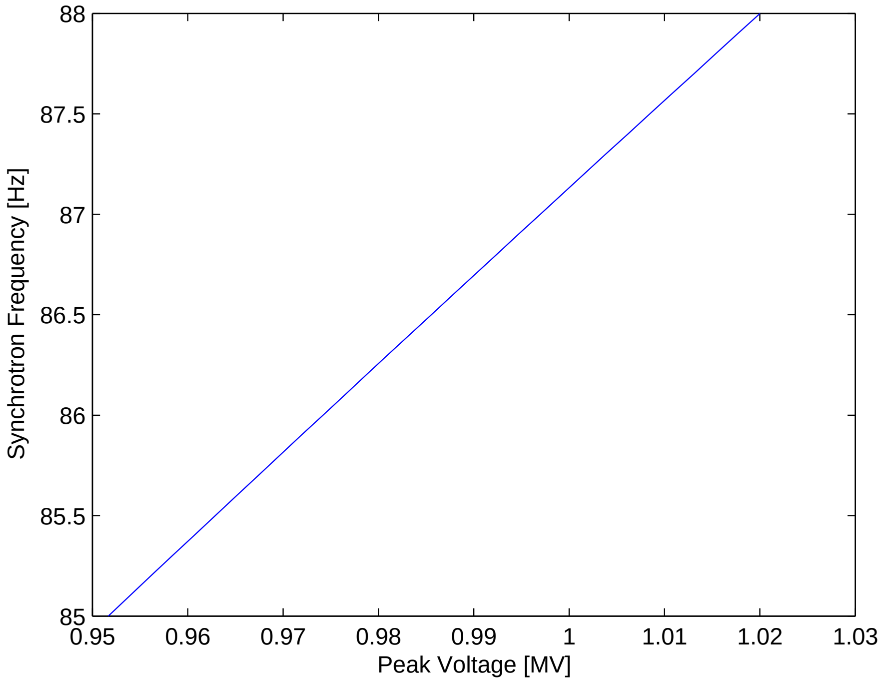

Fig. 1: Synchrotron Frequency Vs Cavity Peak Voltage.

If we assume the synchrotron frequency to be around 86 to 87 Hz at 150 GeV then according to Figure 1 the peak accelerating voltage should be around 0.97 to 1.0 MV assuming a compaction factor $\alpha = 2.82 \times 10^{-3}$. From RF measurements (parameter T:RFSUM in ACNET), V$\simeq$1.12 MV/m. Therefore, the peak accelerating voltage measured from the synchrotron frequency is between 10 to 13 percent lower than given by the RF measurements. Figure 2 shows the evolution of the synchrotron frequency as a function of the peak accelerating voltage for three different values of the momentum compaction.

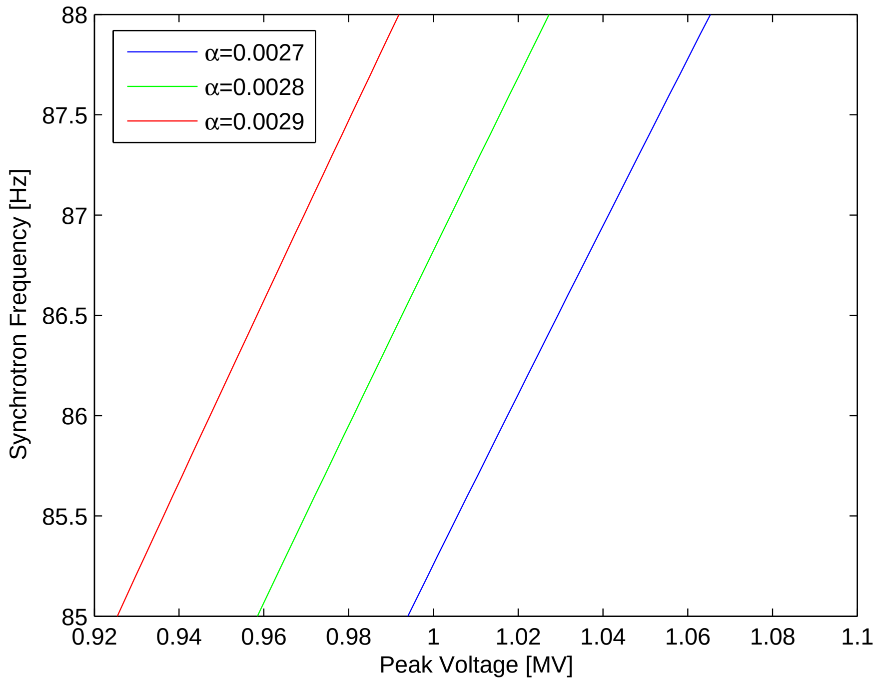

Fig. 2: Synchrotron frequency Vs cavity peak voltage for 3 compaction factor values.

Figure 4 shows the evolution of the synchronous phase ϕ_s during the ramp for the store 4088 (7^{th} of April 2005, from 6:12 to 6:15 am). The output of the Longitudinal Phase Monitor LPM001 (monitoring proton bunch Number 1) is compared with the synchronous phase computed from the bunch centroid (T:SBDPCS[1]) and the from the beam energy.

Figure 3 shows the corresponding bunch centroid during the ramp, in a scale of nanoseconds (left axis) and meters (right axis). The bunch centroid is converted into phase using the relation:

$$\phi_s = \omega_0 t - k_0 z \tag{2}$$

with $\omega_0 = 2\pi f_0$, $k_0 = \frac{2\pi}{\lambda_0}$ and $\lambda_0 = \frac{c}{f_0}$, $f_0 = 53.104$ MHz being the RF frequency.
At each turn, the accelerating cavities give to the beam an energy gain δK equal to :

$$\delta K = q\hat{V}_{rf} \sin\phi_s \tag{3}$$

which can be expressed also as :

$$\delta K = q 2\pi R^2 \dot{B} \tag{4}$$

Combining equations 3 and 4 led to :

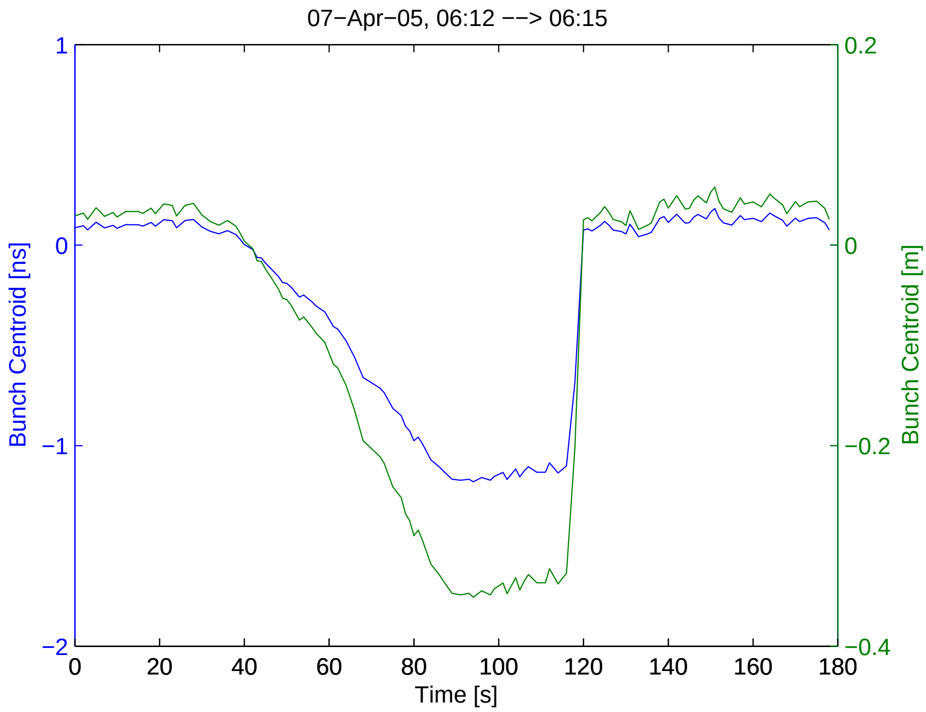

Fig. 3: Bunch centroid from T:SBDPCS[1] during ramp (Store 4088)

$$\phi_s = \arcsin\left(\frac{2\pi R\dot{B}}{\hat{V}_{rf}}\right) \tag{5}$$

References

[1] V. Lebedev, "Lattice measurement, injection errors, diagnostics", DoE Review, July 21-22, 2003, Fermilab.

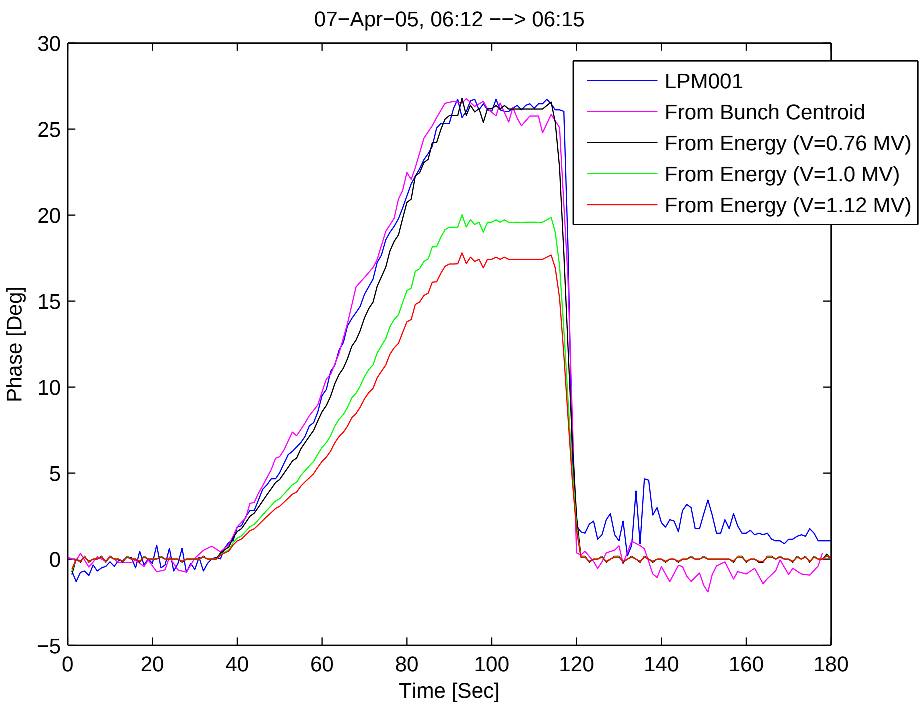

Fig. 4: Synchronous phase ϕ_s measured from the Longitudinal Phase Monitor LPM001 compared to ϕ_s extracted from the bunch centroid SBDPCS[1] and the beam energy for an accelerating voltage of 0.76, 1.0 and 1.12 MV/m.